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FOR ONBOARD NAVIGATION (ONAV) GROUND BASED
EXPERT/TRAINER SYSTEM: FINAL USER'S GUIDE
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Research and Development for Onboard Navigation (ONAV) Ground Based Expert/Trainer System Final User's Guide

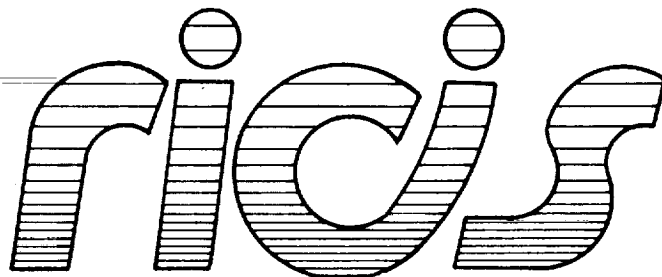
Daniel C. Bochsler

LinCom Corporation

April 12, 1988

**Cooperative Agreement NCC 9-16
Research Activity AI.8**

**NASA Johnson Space Center
Mission Support Directorate
Mission Planning and Analysis Division**



**Research Institute for Computing and Information Systems
University of Houston - Clear Lake**

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The RICIS Concept

The University of Houston-Clear Lake established the Research Institute for Computing and Information systems in 1986 to encourage NASA Johnson Space Center and local industry to actively support research in the computing and information sciences. As part of this endeavor, UH-Clear Lake proposed a partnership with JSC to jointly define and manage an integrated program of research in advanced data processing technology needed for JSC's main missions, including administrative, engineering and science responsibilities. JSC agreed and entered into a three-year cooperative agreement with UH-Clear Lake beginning in May, 1986, to jointly plan and execute such research through RICIS. Additionally, under Cooperative Agreement NCC 9-16, computing and educational facilities are shared by the two institutions to conduct the research.

The mission of RICIS is to conduct, coordinate and disseminate research on computing and information systems among researchers, sponsors and users from UH-Clear Lake, NASA/JSC, and other research organizations. Within UH-Clear Lake, the mission is being implemented through interdisciplinary involvement of faculty and students from each of the four schools: Business, Education, Human Sciences and Humanities, and Natural and Applied Sciences.

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A major role of RICIS is to find the best match of sponsors, researchers and research objectives to advance knowledge in the computing and information sciences. Working jointly with NASA/JSC, RICIS advises on research needs, recommends principals for conducting the research, provides technical and administrative support to coordinate the research, and integrates technical results into the cooperative goals of UH-Clear Lake and NASA/JSC.

***Research and Development for Onboard
Navigation (ONAV)
Ground Based Expert/Trainer System
Final User's Guide***

Preface

This research was conducted under the auspices of the Research Institute for Computing and Information Systems by LinCom Corporation under the direction of Daniel C. Bocshsler. Terry Feagin, Professor of Computer Science at the University of Houston-Clear Lake, served as the technical representative for RICIS.

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The views and conclusions contained in this report are those of the author and should not be interpreted as representative of the official policies, either express or implied, of NASA or the United States Government.

**USER'S GUIDE FOR THE ONBOARD NAVIGATION (ONAV)
CONSOLE EXPERT/TRAINER SYSTEM**

ENTRY PHASE

Final Version

April 1988

LinCom Corporation
Houston Texas

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Section 1

SUMMARY

This document guides the user in operating the ENTRY phase of the Onboard Navigation (ONAV) Console Expert/Trainer system. Included is an overview of the program, system configurations, execution instructions, and maintenance information.

(ONAV)

Section 2

INTRODUCTION

2.1 PURPOSE

The purpose of this document is to present procedures for preparation, operation, monitoring, and recovery of the Shuttle Entry phase expert system. This user's guide is primarily intended for functional users of the system. It includes procedures for system operation in support of training activities as well as operational tasks. In addition, information is provided which enables maintenance personnel to handle updates, modifications, etc. to the system.

Section 3

PROGRAM OVERVIEW

3.1 PROCESS STRUCTURE & DATA FLOW

The ONAV Entry system can be considered to have two different configurations that can be run, depending upon the type of activity desired by a user. The first configuration, called "standard," represents the mode by which the system would be expected to resemble operational use. The second configuration, called "training," includes the coordinated use of a simulated display like those currently used in the Mission Control Center. The intent here is to give a user a feeling for how the expert system is performing as compared to the human interpretations of current control center display screen data.

3.1.1 Standard Configuration

The figure 3.1.1-1 is a diagram of the ONAV Entry system which does not use a simulated MCC display screen. The overall operation begins when the user starts the "entry" process. This process is the actual expert system, embedded within various interface functions. A "data preparation" process is then started, after "entry" processing proceeds through setup and loading procedures. The data preparatio process handles the data input into the expert system. Once execution begins, a "keyboard" process is begun where user control of the expert system is handled during later stages of setup and during execution. These processes continue to execute until rule execution ceases, at which point the keyboard process activity changes to handle either complete termination of the expert system execution, or other rerun efforts if desired.

3.1.2 Training Configuration

The figure 3.1.2-1 is a diagram of the ONAV entry system with the simulated MCC display activity. Operation of this configuration begins with the setup of the simulated MCC display (or MSK). A Unix "pipe" is setup to enable the data stream to be split and sent to both the expert system and the MSK. Once the MSK display is started (this is done on a display different from the one for the ONAV Entry display), then the system activity is similar to that for the standard configuration.

Figure 3.1.1-1: Standard ONAV Entry Configuration Diagram

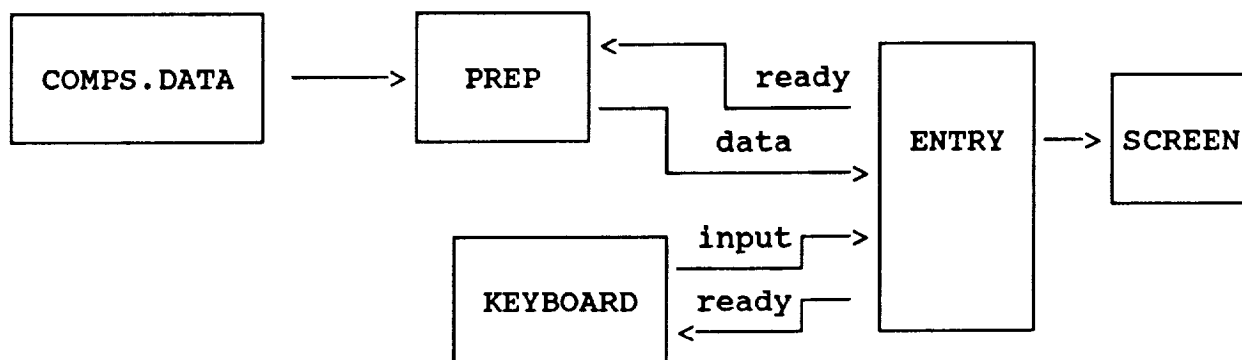
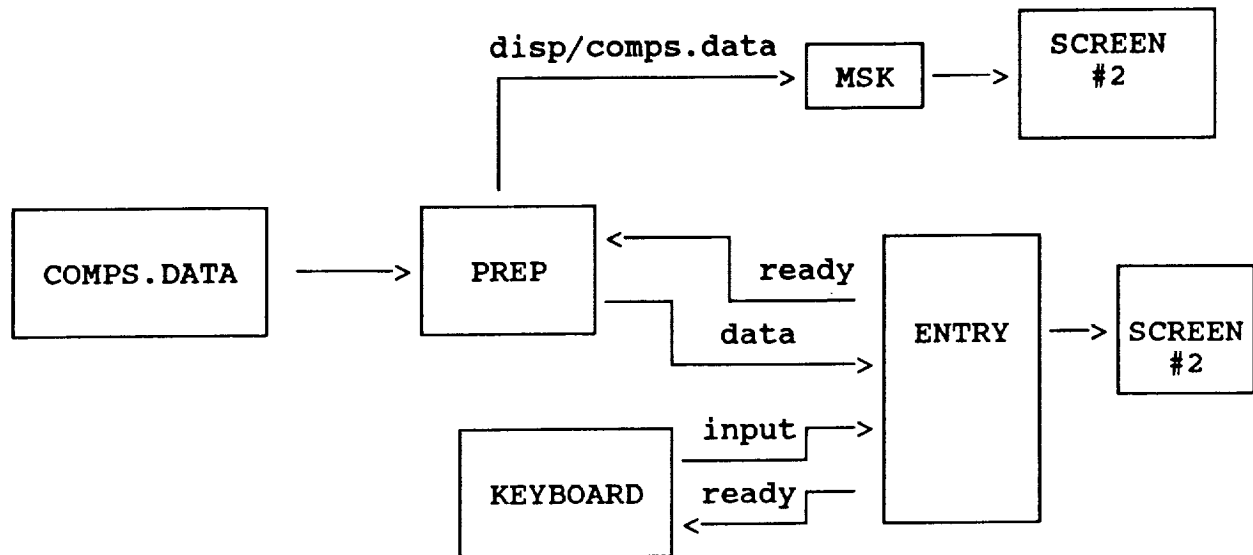


Figure 3.1.2-1: Training Configuration Overview Diagram



Section 4

HARDWARE & SOFTWARE CONFIGURATION

The ONAV Entry system was developed with the idea of being as portable as possible. Unix, C, and Fortran being commonly available on many types of computer system, this objective can be met. The current system was developed primarily on a Hewlett-Packard HP9000 system, and ported at various times during development to other systems including Sun and Masscomp. The key feature of the expert system sensitive to portability is the screen interface. The existing design uses Curses windowing software to provide the various regions on the screen. There are variations to curses which occur when moving from computer to computer. For example, due to time constraints, the porting of the expert system to the Sun and Masscomp systems did not include porting of the interface. This is the prime consideration that must be considered when planning to introduce the Entry system into a computer environment, even other Hewlett-Packard systems.

4.1 HARDWARE REQUIREMENTS

The following hardware is necessary for operating the expert system:

- o HP: - HP9000 computer (with Curses)
 - Second terminal (for MSK simulator)
- o SUN: - Sun Workstation (with Curses)
 - Suntools software (for MSK simulator)
- o Masscomp: - Masscomp (workstation model with Curses)
 - Windowing software
- o Apollo: - Apollo workstation (with Curses)

4.2 SOFTWARE REQUIREMENTS

The following software is necessary to operate the expert system:

- o All: - CLIPS expert system shell (V4.1)
 - Entry source and associated support code.
 - Unix system software

Section 5

PROGRAM EXECUTION INSTRUCTIONS

5.1 DIRECTORY STRUCTURE

The ONAV Entry system consists of many software components. These have been organized into several logical groups to facilitate utilization and configuration management activities. Table 5.1-1 lists the various file directories and describes the contents of each.

5.2 STARTING THE EXPERT SYSTEM PROGRAM

The command at the Unix system prompt to initiate the expert system has the following form:

_____ optional

entry [arg1] [arg2] [noload]

name of data _____ prep program	_____ name of keyboard program
------------------------------------	-----------------------------------

Currently, arg1 and arg2 are specified as **prep** and **keyboard** respectively. Specifying "noload" causes the program to proceed directly to the CLIPS command loop. Omitting "noload" (the normal operating method) causes the entire rulebase to be loaded. Rule files are loaded from the directory named in the UNIX environment variable "rulebase". One can view the UNIX environment variables with a Unix "env" command. Setting "rulebase" can be done via direct commands at the Unix system prompt or the commands can be put in a user's top level directory file ".profile" or ".login" command. An example of setting the "rulebase" variable and starting execution of the system is shown in figure 5.2-1.

Table 5.1-1: ONAV Entry File Structure and Contents

NOTE:

The following file structure references are described in general as they pertain to the expert system. Specific path names, etc. will obviously vary slightly depending upon system characteristics and administrative procedures in place for a computer system with the ONAV Entry system installed.

- 1) Top Node: /users/onaves

 The top node should contain four types of files:
 - executable files
 - input data file (comps.data)
 - landing site table
 - window definition files
- 2) Directory logtape contains
 - delog output binary file (delog.bin)
 - log tape preprocessor (logcomps)
 - data repairs (repairs)
- 3) Directory data contains
 - data preparation source code
 - test drivers for line-fit, moving avg and filter
- 4) Directory disp contains
 - MSK simulator source code
 - pipe from data prep process
- 5) Directory key contains
 - keyboard handler source code
- 6) Directory exsys contains
 - expert system source & rules
- 7) Directory exsys/source contains
 - CLIPS 4.1 first release

Figure 5.2-1: Setting Unix Variables and Starting ONAV Entry

```
$  
$  
$ rulebase=exsys/ } for Unix 4.2:  
$ export rulebase } setenv rulebase exsys/  
  
$ entry prep keyboard  
Welcome to the Entry ONAV Expert System  
Load in progress; please stand by...  
loading control/data rules  
loading landing site rules  
loading state rules  
loading imu rules  
loading 3-state rules  
loading drag rules  
loading tacan rules  
loading baro rules  
loading msbls rules  
loading hstd rules  
loading telemetry rules  
Don't forget to reset CLIPS  
CLIPS>
```

5.3 CONFIGURING THE EXPERT SYSTEM

After the system has finished loading the rules, various types of operator inputs can be performed to set system parameters to the proper initial values. This activity begins by performing a RESET and ONAV command at the CLIPS expert system prompt after all the rule load messages have been received on the screen, as shown in figure 5.3-1. The reset performs an initialization of the CLIPS expert system. The onav command activates the ONAV Entry display screen and causes the system to wait for operator input via the system menu. Figure 5.3-2 shows the terminal screen after the ONAV display has been activated.

This configuration of the display is called the "stopped" configuration. Down in the lower right hand corner of the display are menu selection choices for the "system menu." The GO command causes the expert system to begin execution. The CONFIG command is used to change initial configuration data items prior to executing the expert system. The RESET command resets the CLIPS expert system and recycles input data, and clears the screen prior to beginning execution. The EXIT command terminates all processing and returns you to the Unix system prompt. Normal usage of these commands is as follows: 1) config, 2) reset, and 3) go. Exit is used after a "run" has been made. Additionally, a "hidden" command of "z" is available, but not listed on the system menu. This command interrupts the expert system and returns processing to the CLIPS prompt.

5.3.1 Using the CONFIG Command

The CONFIG command is invoked from the stopped configuration menu by typing the character "c" (upper or lower case can be used). No carriage return is necessary; the system is scanning for a single character input. A submenu is overlaid on the screen as shown in figure 5.3.1-1.

The four items listed represent the four parameters in the system that can be configured currently. Runway refers to setting the designated runway (e.g. EDW17), Tacan refers to setting the primary or secondary runway, Atmosphere model refers to selection of a normal, hot, or cold atmosphere, and BFS status refers to indicating whether the BFS system is go or no-go. It should be noted that tacan is normally set automatically when the runway is selected, therefore is not normally configured explicitly.

Figure 5.3-1: Resetting and Activating the ONAV Display Screen

```
$  
$ rulebase=exsys/      } for Unix 4.2:  
$ export rulebase      } setenv rulebase exsys/
```

\$ entry prep keyboard
Welcome to the Entry ONAV Expert System
Load in progress; please stand by...
loading control/data rules
loading landing site rules
loading state rules
loading imu rules
loading 3-state rules
loading drag rules
loading tacan rules
loading baro rules
loading msbls rules
loading hstd rules
loading telemetry rules
Don't forget to reset CLIPS
CLIPS> (reset)
CLIPS> (onav)

Figure 5.3-2: Stopped Configuration of Display after Activation

ONBOARD NAVIGATION EXPERT SYSTEM			
PRI	BFS	GND	
1-SITE RW			
TAC			
2-STATE			
LRU	1	2	3
3-3STAT			
4-PIMU			
5-BIMU			
6-DRAG			
7-TAC RNG			
BRG			
8-BARO			
9-MLS RNG			
AZ			
EL			
TLM			
CONFIGURATION SUMMARY			
rw	tac		
atm			
bfs			
delta			
SYSTEM SUMMARY		SYSTEM MENU	
MISSED CYCLES		go	config
PHASE		reset	exit
MODE			

Figure 5.3.1-1: CONFIG Command Submenu

PRI	BFS	GND	ONBOARD NAVIGATION EXPERT SYSTEM
1-SITE RW			
TAC			
2-STATE			
LRU	1	2	3
3-3STAT			
4-PIMU			
5-BIMU			
6-DRAG			
7-TAC RNG			
BRG			
8-BARO			
9-MLS RNG			
AZ			
EL			
TLM			
CONFIGURATION SUMMARY			
rw		tac	
atm			
bfs			
delta			
SYSTEM SUMMARY			SYSTEM MENU
MISSED CYCLES			go
PHASE			config
MODE			reset
			exit

The configuration selections are individually selected and can be performed in any order. They can also be repeated if a typographical error is made or the desired initial value needs to be changed prior the beginning execution of the expert system. Each time a parameter is set, the display returns to the stopped configuration. There the CONFIG command is selected and the parameter is selected and performed. This is different from what some might expect in that after the parameter is changed, the configuration selection menu is not redisplayed. A user has to invoke the configuration command to get back to the configuration parameter list. Figures 5.3.1-2 through 5.3.1-10 illustrate a series of actions where the various parameters are set.

5.3.1.1 Runway Selection

Note that the runway selection requires a runway designation to be typed in; CAPITAL letters must be used in the designator. After a carriage return, the display returns to the stopped menu configuration, but the configuration summary in the bottom left of the display is updated to reflect the changes you make.

5.3.1.2 Tacan Selection

The tacan menu permits the selection of a primary or secondary tacan channel combination.

5.3.1.3 Atmosphere Selection

Selection of an atmosphere requires that the first letter of the desired selection be typed, although no carriage return is necessary (n - nominal, h - hot, c - cold). Again the display returns to the stopped menu configuration and the configuration summary is updated to show the atmosphere model selected.

5.3.1.4 BFS Status Selection

The status of the BFS system is selected by typing the first letter of the desired selection. The stopped configuration menu then is redisplayed and the configuration summary is updated.

Figure 5.3.1-2: Runway Parameter Selection Menu

1-SITE RW		2-STATE		3-3STAT		4-PIMU		5-BIMU		6-DRAG		7-TAC RNG		8-BARO		9-MLS RNG		AZ		EL		TLM	
PRI	BFS	GND																					
ONBOARD NAVIGATION EXPERT SYSTEM																							
ENTER RUNWAY NAME																							
CONFIGURATION SUMMARY												SYSTEM SUMMARY											
rw												SYSTEM MENU											
atm												go											
bfs												config											
delta												reset											
												exit											

Figure 5.3.1-3: Entering a Runway Designation

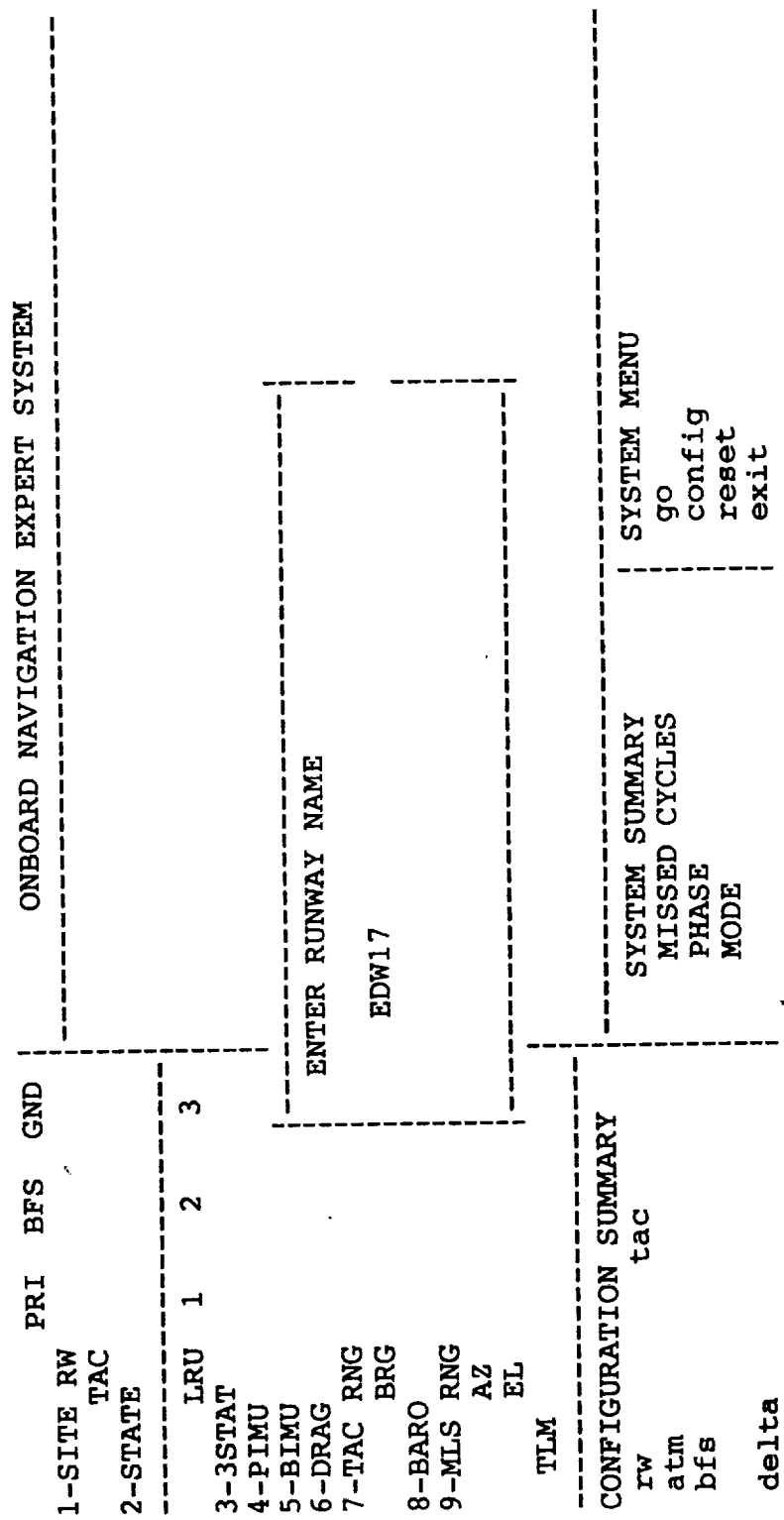


Figure 5.3.1-4: Redisplay of Stopped Display with Runway Update

ONBOARD NAVIGATION EXPERT SYSTEM		
PRI	BFS	GND
1-SITE RW		
TAC		
2-STATE		
LRU	1	2 3
3-3STAT		
4-PIMU		
5-BIMU		
6-DRAG		
7-TAC RNG		
BRG		
8-BARO		
9-MLS RNG		
AZ		
EL		
TLM		
CONFIGURATION SUMMARY		
rw	EDW17	tac 111
atm		
bfs		
delta		
SYSTEM SUMMARY		SYSTEM MENU
MISSED CYCLES		go
PHASE		config
MODE		reset
		exit

Figure 5.3.1-5: Tacan Parameter Selection Menu

		PRI	BFS	GND	ONBOARD NAVIGATION EXPERT SYSTEM
1-SITE RW					
TAC					
2-STATE					
		LRU	1	2	3
3-3STAT					
4-PIMU					
5-BIMU					
6-DRAG					
7-TAC RNG					
BRG					
8-BARO					
9-MLS RNG					
AZ					
EL					
TLM					
CONFIGURATION SUMMARY					
rw	EDW17	tac	111		
atm					
bfs					
delta					
CHOOSE A TACAN					
primary 111					
secondary 92					
SYSTEM SUMMARY					
MISSED CYCLES					
PHASE					
MODE					
SYSTEM MENU					
go					
config					
reset					
exit					

Figure 5.3.1-6: Redisplay of Stopped Display with Tacan Update

ONBOARD NAVIGATION EXPERT SYSTEM			
PRI	BFS	GND	
1-SITE RW			
TAC			
2-STATE			
LRU	1	2	3
3-3STAT			
4-PIMU			
5-BIMU			
6-DRAG			
7-TAC RNG			
BRG			
8-BARO			
9-MLS RNG			
AZ			
EL			
TLM			
CONFIGURATION SUMMARY			
rw	EDW17	tac	92
atm			
bfs			
delta			
SYSTEM SUMMARY		SYSTEM MENU	
MISSED CYCLES		go	config
PHASE		reset	
MODE		exit	

Figure 5.3.1-7: Atmosphere Selection Menu

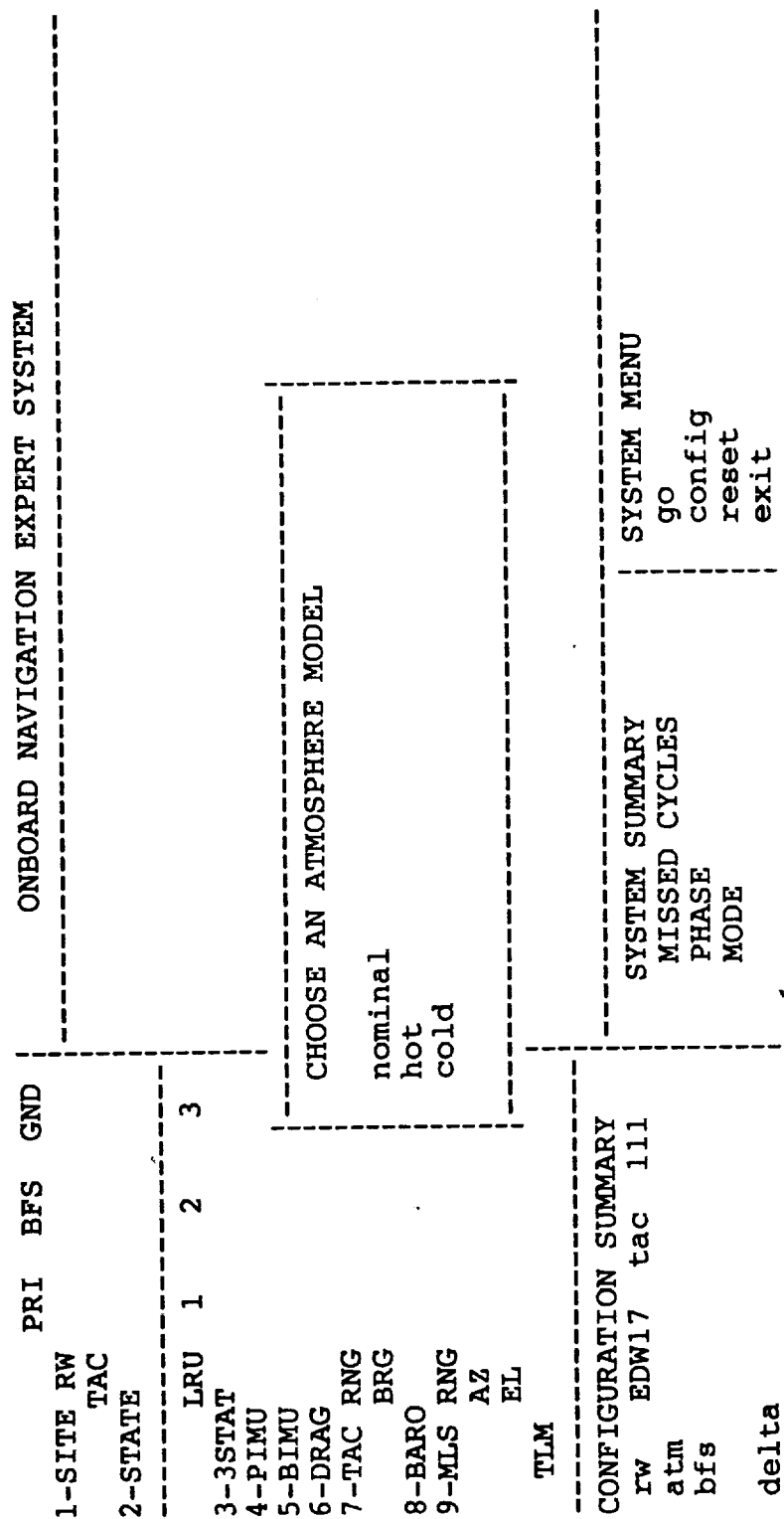


Figure 5.3.1-8: Stopped Display with Atmosphere Updates

ONBOARD NAVIGATION EXPERT SYSTEM			
PRI	BFS	GND	
1-SITE RW			
TAC			
2-STATE			
LRU	1	2	3
3-3STAT			
4-PIMU			
5-BIMU			
6-DRAG			
7-TAC RNG			
BRG			
8-BARO			
9-MLS RNG			
AZ			
EL			
TLM			
CONFIGURATION SUMMARY			
rw	EDW17	tac	111
atm	nominal		
bfs			
delta			
SYSTEM SUMMARY		SYSTEM MENU	
MISSED CYCLES		go	
PHASE		config	
MODE		reset	
		exit	

Figure 5.3.1-9: BFS Status Selection Menu

PRI		BFS	GND	ONBOARD NAVIGATION EXPERT SYSTEM	
1-SITE RW					
TAC					
2-STATE					
LRU	1	2	3		
3-3STAT					
4-PIMU					
5-BIMU					
6-DRAG					
7-TAC RNG					
BRG					
8-BARO					
9-MLS RNG					
AZ					
EL					
TLM					
CONFIGURATION SUMMARY				SYSTEM SUMMARY	
rw	EDW17	tac	111	SYSTEM MENU	
atm	nominal			go	
bfs				config	
				reset	
				exit	
delta					

Figure 5.3.1-10: Stopped Display with BFS Status Updates

ONBOARD NAVIGATION EXPERT SYSTEM			
PRI		BFS	GND
1-SITE RW			
TAC			
2-STATE			

LRU	1	2	3
3-3STAT			
4-PIMU			
5-BIMU			
6-DRAG			
7-TAC RNG			
BRG			
8-BARO			
9-MLS RNG			
AZ			
EL			
TLM			

CONFIGURATION SUMMARY			
rw	EDW17	tac	111
atm	nominal		
bfs	go		
delta			

SYSTEM SUMMARY		SYSTEM MENU	
MISSED CYCLES		go	
PHASE		config	
MODE		reset	
		exit	

5.3.2 Using the RESET Command

The reset command is invoked from the stopped configuration menu by typing a "r" (upper or lower case is recognized by the system). No carriage return is necessary, since the background routine monitoring the keyboard is looking for single character inputs. This command, although the same as the CLIPS reset command described earlier in this document, does more than just reset the CLIPS expert system. It also "recycles" input data so that the input data file that the ONAV Entry system will use is properly set up. This reset is always required prior to starting execution of the expert system.

5.3.3 Using the GO Command

The GO command is invoked on the stopped configuration menu by typing a "g" (upper or lower case is recognized). Again, no carriage return is necessary. This is the command that actually starts the execution of the system. The first result to be noticed is that the display is altered somewhat in that a different set of system menu selections is displayed. This is shown in figure 5.3.3-1. The overall display at this point is then called the "running" configuration. Various background processing is taking place at this point, although no activity is visible on the screen for several seconds after the system menu selections change.

5.3.4 Using the EXIT Command

The EXIT command is invoked from the stopped configuration menu by typing the character "e". This stops all processing in progress and returns the user to the Unix operating system prompt for the computer system being used.

5.4 MONITORING EXECUTION

After the GO command is given and the running configuration is displayed, the system begins performing the monitoring of incoming data. Messages begin to show up on the display in the large window area, and status lights begin to be set on the left side of the display. Figure 5.4-1 illustrates this situation. It should be noted that the messages scroll down the message window from top to bottom.

Figure 5.3.3-1: Running Configuration Screen After GO Command

ONBOARD NAVIGATION EXPERT SYSTEM	
PRI	BFS GND
1-SITE RW	
TAC	
2-STATE	
LRU	1 2 3
3-3STAT	
4-PIMU	
5-BIMU	
6-DRAG	
7-TAC RNG	
BRG	
8-BARO	
9-MLS RNG	
AZ	
EL	
TLM	
CONFIGURATION SUMMARY	
rw	EDW17 tac 111
atm	nominal
bfs	go
delta	
SYSTEM SUMMARY	
MISSED CYCLES	
PHASE	
MODE	
SYSTEM MENU	
stop	runway
toggle tacan	good hstd
posn delta	bad hstd
vel&posn delta	no-go-bfs
delta cancelled	

Figure 5.4-1: ONAV Entry Display as System begins to Run

ONBOARD NAVIGATION EXPERT SYSTEM				12:59:40
1-SITE RW	PRI	BFS	GND	
TAC	GO	GO		
2-STATE	TAC	GQ	BAD	
3-3STAT	LRU	1	2	3
4-PIMU	GOOD	GOOD	GOOD	GOOD
5-BIMU	GOOD	GOOD	GOOD	GOOD
6-DRAG	GOOD	GOOD	GOOD	GOOD
7-TAC RNG	BRG			
8-BARO				
9-MLS RNG				
AZ				
EL				
TLM				

CONFIGURATION SUMMARY				
rw	EDW17	tac	111	
atm	nominal			
bfs	go			
delta				

* 12:59:37 133 kft Drag should be returned to auto in the pass				
12:59:35 134 kft TACAN bearing data-good flag is on				
12:59:35 134 kft TACAN range data-good flag is on				
12:59:35 134 kft TACAN 1 is locking onto bearing				
12:59:35 134 kft TACAN 1 is locking onto range				
12:59:35 134 kft MSBLS 1 range is good				
12:59:35 134 kft The bfs has the correct runway selected				
12:59:35 134 kft The pass has the correct runway selected				
12:59:35 134 kft TACAN is now on channel 111				
12:59:35 mach 6 Air data is crew call				

SYSTEM SUMMARY		SYSTEM MENU		
MISSED CYCLES		toggle tacan	stop	runway
PHASE		posn delta	good hstd	good hstd
MODE		vel&posn delta	bad hstd	bad hstd
		delta cancelled	no-go	no-go-bfs

5.4.1 Display Messages

Messages resulting from the expert system's monitoring of all onboard Shuttle navigation sensor systems are displayed in the message window area. The messages consist of four parts:

- 1) a time tag which references the message to mission time,
- 2) an altitude or mach number reference which gives more meaning to the message itself, and
- 3) the text of the message.

In addition, each message may have emphasis placed on it for better visual attention through the use of both inverse video and/or asterisks on the far left of the message. The four types of visual enhancements have the following defined meanings:

- a) A **NOMINAL EVENT NOTICE** is displayed in normal type.
- b) An **OFF-NOMINAL EVENT NOTICE** is displayed with an inverse video highlight.
- c) A **NOMINAL RECOMMENDATION** is displayed with an asterisk at the beginning of the message.
- d) An **OFF-NOMINAL RECOMMENDATION** is displayed with an asterisk and with inverse video highlight.

5.4.2 Subsystem Status Indicators

The status indicators along the left side of the display are used as "quick" scan information that can give a qualitative, visual measure of the status of an individual sensor system as monitored by the expert system. Each sensor will have notations that show up in each of the columns which correspond to LRU's of the sensor system. Those systems which have only one unit are indicated in the column for LRU 1. Each subsystem has an identification label on the display consisting of a 3-5 letter abbreviation. In front of each abbreviation is a number (e.g., 6 for drag). This number is a subwindow selection number used to select a specialized message window for the corresponding sensor subsystem.

5.4.3 Subsystem Message Windows

A special message window can be displayed for each sensor subsystem. Whereas the overall system message window displays all messages, a subwindow displays that subset of all messages that relate to the specific sensor system. Any subwindow may be displayed by typing the number of the desired subwindow. No carriage return is necessary.

While viewing a subwindow, new messages for that subsystem will be displayed as they occur. As noted earlier, each subwindow has a non-zero number assigned to it as noted by the sensor name label on the display. If a person desires to look at some other subwindow, after viewing a given subwindow, simply type the desired number for the subwindow. If the overall system window with all messages is desired, the number 0 (zero) should be typed (again, no carriage return is needed). The current state of all visible messages is then displayed. Figures 5.4.3-1 through 5.4.3-9 show examples of each of the subwindows. It should be noted that if no messages have been generated for a particular sensor subsystem, the subwindow for that system will be blank except for the subwindow label at the top of the message area.

Figure 5.4.3-1: Landing Site Subwindow Example

ONBOARD NAVIGATION EXPERT SYSTEM				13:00:43
1-SITE	RW	PRI	BFS	GND
	TAC	GO	GO	
2-STATE				BAD

3-3STAT	LRU	1	2	3
4-PIMU		GOOD	GOOD	GOOD
5-BIMU		GOOD	GOOD	GOOD
6-DRAG		GOOD	GOOD	GOOD
7-TAC	RNG			
8-BARO	BRG			
9-MLS	RNG			
	AZ			
	EL			
TLM				

CONFIGURATION SUMMARY				
rw	EDW17	tac	111	
atm	nominal			
bfs	go			
delta				

LANDING SITE	
12:59:35	134 kft The bfs has the correct runway selected
12:59:35	134 kft The pass has the correct runway selected

Figure 5.4.3-2: State Vectors Subwindow Example

ONBOARD NAVIGATION EXPERT SYSTEM			13:01:05
STATE VECTORS			
13:00:47 111 kft BFS transfer is in			
1-SITE	RW	GND	
	TAC	GO	
2-STATE	GO	GO	
		BAD	
3-3STAT	LRU	1	2
4-PIMU	GOOD	GOOD	GOOD
5-BIMU	GOOD	GOOD	GOOD
6-DRAG	GOOD	GOOD	GOOD
7-TAC	RNG	BRG	
8-BARO			
9-MLS	RNG	AZ	
		EL	
	TLM		
CONFIGURATION SUMMARY			
rw	EDW17	tac	111
atm	nominal		
bfs	go		
delta			

Figure 5.4.3-3: Three String State Vectors Subwindow Example

ONBOARD NAVIGATION EXPERT SYSTEM				13:01:19
THREE STRING STATE VECTORS				
1-SITE	RW	PRI	BFS	GND
		GO	GO	
2-STATE	TAC	GO		BAD
3-3STAT	LRU	1	2	3
		GOOD	GOOD	GOOD
4-PIMU		GOOD	GOOD	GOOD
5-BIMU		GOOD	GOOD	GOOD
6-DRAG				
7-TAC	RNG	GOOD		GOOD
	BRG			
8-BARO				
9-MLS	RNG			
	AZ			
	EL			
TLM				
CONFIGURATION SUMMARY				
rw	EDW17	tac	111	
atm	nominal			
bfs	go			
delta				

Figure 5.4.3-4: PASS IMU Subwindow Example

ONBOARD NAVIGATION EXPERT SYSTEM				13:06:28
PASS IMU				
1-SITE	RW	PRI	BFS	GND
	TAC	GO	GO	
2-STATE				BAD
		LRU	1	2
3-3STAT			BAD	GOOD
4-PIMU			GOOD	COMF
5-BIMU			GOOD	COMF
6-DRAG				
7-TAC	RNG	OFF	OFF	OFF
	BRG	OFF	OFF	OFF
8-BARO				
9-MLS	RNG	GOOD	COMF	GOOD
	AZ	GOOD	COMF	GOOD
	EL	GOOD	COMF	GOOD
TLM				
CONFIGURATION SUMMARY				
rw	EDW17	tac	111	
atm	nominal			
bfs	go			
delta				

Figure 5.4.3-5: BFS IMU Subwindow Example

ONBOARD NAVIGATION EXPERT SYSTEM				13:06:12
13:01:41 98 kft BFS is now on IMU 1				
BFS IMU				
1-SITE	RW	PRI	BFS	GND
		GO	GO	
2-STATE	TAC	GO		BAD
3-3STAT	LRU	1	2	3
		BAD	GOOD	BAD
4-PIMU		GOOD	COMF	GOOD
5-BIMU		GOOD	COMF	GOOD
6-DRAG				
7-TAC	RNG	OFF	OFF	OFF
	BRG	OFF	OFF	OFF
8-BARO				
9-MLS	RNG		COMF	
	AZ		COMF	
	EL	GOOD	COMF	GOOD
TLM				
CONFIGURATION SUMMARY				
rw	EDW17	tac	111	
atm	nominal			
bfs	go			
delta				

Figure 5.4.3-6: Drag Altitude Subwindow Example

ONBOARD NAVIGATION EXPERT SYSTEM				13:01:41
DRAG ALTITUDE				
13:01:27 103 kft Processing drag				
1-SITE	RW	PRI	BFS	GND
		GO	GO	
2-STATE	TAC	GO		BAD

LRU	1	2	3	
3-3STAT	GOOD	GOOD	GOOD	GOOD
4-PIMU	GOOD	COMF	GOOD	GOOD
5-BIMU	GOOD	COMF	GOOD	GOOD
6-DRAG				
7-TAC	RNG	GOOD	COMF	GOOD
	BRG		COMF	
8-BARO				
9-MLS	RNG	COMF		
	AZ	COMF		
	EL	COMF		
TLM				

CONFIGURATION SUMMARY				
rw	EDW17	tac	111	
atm	nominal			
bfs	go			
delta				

Figure 5.4.3-7: TACAN Subwindow Example

ONBOARD NAVIGATION EXPERT SYSTEM				13:02:02
1-SITE	RW	GO	GO	
2-STATE	TAC	GO		

3-3STAT	GOOD	BAD	BAD	
4-PIMU	GOOD	COMF	GOOD	
5-BIMU	GOOD	COMF	GOOD	
6-DKAG				
7-TAC	RNG	GOOD	COMF	GOOD
8-BARO	BRG		COMF	
9-MLS	RNG		COMF	
AZ			COMF	
EL			COMF	
TLM				

CONFIGURATION SUMMARY				
rw	EDW17	tac	111	
atm	nominal			
bfs	go			
delta				

TACAN

13:01:50 95 kft TACAN bearing data-good flag is on
 13:01:47 96 kft TACAN bearing data-good flag is off
 13:01:45 97 kft TACAN range data-good flag is on
 13:01:43 98 kft TACAN range data-good flag is off
 13:01:15 106 kft Processing TACAN bearing
 13:01:15 106 kft Processing TACAN range
 13:01:09 106 kft ONAV can't determine which TACAN LRU caused the TACAN 1 range quality change
 13:01:09 106 kft Tacan 1 range quality has changed from unknown to good
 13:01:09 106 kft ONAV can't determine which TACAN LRU caused the TACAN 3 range quality change
 13:01:09 106 kft Tacan 3 range quality has changed from unknown to good
 12:59:35 134 kft TACAN bearing data-good flag is on
 12:59:35 134 kft TACAN range data-good flag is on
 12:59:35 134 kft TACAN 1 is locking onto bearing
 12:59:35 134 kft TACAN 1 is locking onto range

Figure 3.4.3-8: Baro Altitude Subwindow Example

ONBOARD NAVIGATION EXPERT SYSTEM				13:02:25
1-SITE RW	PRI	BFS	GND	
	GO	GO		
2-STATE	TAC	GO		
	LRU	1	2	3
3-3STAT	GOOD	BAD	BAD	
4-PIMU	GOOD	COMF	GOOD	
5-BIMU	GOOD	COMF	GOOD	
6-DRAG	GOOD	COMF	GOOD	
7-TAC	RNG	GOOD	COMF	GOOD
	BRG	OFF	OFF	OFF
8-BARO				
9-MLS	RNG	COMF		
	AZ	COMF		
	EL	COMF		
	TLM			
CONFIGURATION SUMMARY				
rw	EDW17	tac	111	
atm	nominal			
bfs	go			
delta				

BARO ALTITUDE	
13:02:13 mach	3 air data status is statistics
13:02:11 mach	3 air data status is off
13:01:27 mach	4 air data status is statistics
13:01:25 mach	4 air data status is off
13:01:23 mach	4 air data status is statistics
13:01:21 mach	4 air data status is off
13:00:39 mach	5 air data status is statistics
12:59:35 mach	6 Air data is crew call

Figure 5.4.3-9: MSBLS Subwindow Example

ONBOARD NAVIGATION EXPERT SYSTEM				13:06:20
1-SITE RW	PRI	BFS	GND	
TAC	GO	GO		
2-STATE				
LRU	1	2	3	
3-3STAT	BAD	GOOD	BAD	
4-PIMU	GOOD	COMF	GOOD	
5-BIMU	GOOD	COMF	GOOD	
6-DRAG				
7-TAC RNG	OFF	OFF	OFF	
BRG	OFF	OFF	OFF	
8-BARO				
9-MLS RNG	GOOD	COMF	GOOD	
AZ		COMF		
EL	GOOD	COMF	GOOD	
TLM				
CONFIGURATION SUMMARY				
rw	EDW17	tac	111	
atm	nominal			
bfs	go			
delta				

MSBLS

13:06:16 27 kft MSBLS 3 range is good
 13:06:14 27 kft MSBLS range data-good flag is on
 13:06:14 27 kft MSBLS is locking onto range
 13:06:08 28 kft MSBLS 3 elevation is good
 13:06:08 28 kft MSBLS 1 elevation is good
 13:06:04 29 kft MSBLS is locking onto elevation
 12:59:35 134 kft MSBLS 1 range is good

5.5 USER INPUTS DURING EXECUTION

The system menu selections of the ONAV Entry system change between the stopped and running configurations. This is because the nature of the inputs changes from one of "control" of the expert system to one of "providing manual inputs" to the expert system. These manual inputs are required because normal ONAV console operations in the MCC involve use of "voice loop" information by the console operator in their interpretation of sensor data. This verbal data is not available in the data stream which the ONAV Entry expert system uses. Therefore, this manual input method during execution is provided to ensure that the monitoring of sensor subsystems by the expert system is done properly and with the same data as available to human console operators.

The definition of the system menu selection available during execution are as follows:

- 1) STOP halts execution of the expert system at the next data cycle.
- 2) TOGGLE changes the desired Tacan to the other station in a selected Tacan area.
- 3) RUNWAY changes the desired runway. Selection is entered as "Rnn" where "nn" is the 2-digit slot number.
- 4) GOOD HSTD indicates that the ground navigation vector is considered good.
- 5) BAD HSTD indicates that the ground navigation vector is considered bad.
- 6) NO_GO_BFS indicates that the BFS system has been declared to be in a no-go condition.
- 7) POSN DELTA indicates that the GUIDO officer has called a position only delta-state update.
- 8) VEL&POSN DELTA indicates that the GUIDO officer has called a position and velocity delta-state update.
- 9) DELTA CANCELLED indicates that GUIDO officer is not going to do any delta-state update.

Each of these menu selections is invoked by typing the first letter of the name of the selection (e.g., "r" for RUNWAY command). It should be noted that each menu item has a unique first letter. Therefore, menu selection is with the first letter and the background processing looks for an individual character as the input selection.

5.6 STOPPING EXECUTION

As the system continue to execute, messages continue to be generated and more and more of the sensor systems begin to be statused as the data progresses through the various stages of a Shuttle Entry phase activity. Figure 5.6-1 illustrates the appearance of the display at the later stages of a run.

The expert system may stop execution in one of two ways. The first method will be when the system no longer has any more data to operate on. Another way of saying this is that there are no more rules in the expert system that have activated. When this occurs, the selections in the system menu area of the display will change back to the stopped configuration, like that prior to execution.

If a user desires to stop processing while the system is still receiving and monitoring data, the running configuration of the screen provides a STOP command in the system menu. This command is invoked by typing the character "s". This causes the system menu selections to change to the stopped configuration, as illustrated in figure 5.6-2.

After the system is stopped by either method, a user may desire to begin configuration and execution activities again, or a user may want to stop completely. The previously described procedures for doing this can be used at this point.

Figure 3.6-1: ONAV Entry Display at Later Stages of Execution

ONBOARD NAVIGATION EXPERT SYSTEM				13:06:37
1-SITE	RW	GO	GND	
2-STATE	TAC	GO	BAD	
3-3STAT	LRU	1	2	3
4-PIMU	BAD	GOOD	BAD	
5-BIMU	GOOD	COMF	GOOD	
6-DRAG	GOOD	COMF	GOOD	
7-TAC	RNG	OFF	OFF	
8-BARO	BRG	OFF	OFF	
9-MLS	RNG	GOOD	COMF	GOOD
TLM	AZ	GOOD	COMF	GOOD
	EL	GOOD	COMF	GOOD
	CONFIGURATION SUMMARY			
	rw	EDW17	tac	111
	atm	nominal		
	bfs	go		
	delta			
13:06:30 24 kft Processing TACAN bearing				
13:06:26 25 kft TACAN bearing data-good flag is on				
13:06:22 25 kft MSBLS 3 azimuth is good				
13:06:22 25 kft MSBLS 1 azimuth is good				
13:06:20 26 kft MSBLS is locking onto azimuth				
13:06:16 27 kft MSBLS 3 range is good				
13:06:14 27 kft MSBLS range data-good flag is on				
13:06:14 27 kft MSBLS is locking onto range				
13:06:08 28 kft TACAN range data-good flag is on				
13:06:08 28 kft Processing TACAN range				
* 13:02:37 84 kft wrong major mode in pass ;				
Recommend crew call to select				
mm304				
* 13:02:37 84 kft wrong major mode in bfs ;				
Recommend crew call to select				
mm304				
SYSTEM SUMMARY				
MISSED CYCLES				
PHASE				
MODE				
SYSTEM MENU				
toggle tacan				stop
posn delta				runway
vel&posn delta				good hstd
delta cancelled				bad hstd
				no-go-bfs

Figure 5.6-2: ONAV Display after STOP Command is Given

1-SITE RW GO GND TAC GO 2-STATE BAD		ONBOARD NAVIGATION EXPERT SYSTEM 13:06:50	
LRU 1 2 3 3-3STAT BAD GOOD BAD 4-PIMU GOOD COMF GOOD 5-BIMU GOOD COMF GOOD 6-DRAG 7-TAC RNG OFF OFF OFF BRG OFF OFF OFF 8-BARO 9-MLS RNG GOOD COMF GOOD AZ GOOD COMF GOOD EL GOOD COMF GOOD TLM		13:06:30 24 kft Processing TACAN bearing 13:06:26 25 kft TACAN bearing data-good flag is on 13:06:22 25 kft MSBLS 3 azimuth is good 13:06:22 25 kft MSBLS 1 azimuth is good 13:06:20 26 kft MSBLS is locking onto azimuth 13:06:16 27 kft MSBLS 3 range is good 13:06:14 27 kft MSBLS range data-good flag is on 13:06:14 27 kft MSBLS is locking onto range 13:06:08 28 kft TACAN range data-good flag is on 13:06:08 28 kft Processing TACAN range * 13:02:37 84 kft wrong major mode in pass ; Recommend crew call to select mm304 * 13:02:37 84 kft wrong major mode in bfs ; Recommend crew call to select mm304	
CONFIGURATION SUMMARY rw EDW17 tac 111 atm nominal bfs go delta		SYSTEM SUMMARY MISSED CYCLES PHASE MODE	
		SYSTEM MENU go config reset exit	

Section 6

MAINTENANCE & MODIFICATIONS

This section describes several procedures that relate to changing, maintaining, and modifying the ONAV Entry expert system.

6.1 USING AN INCOMPLETE RULEBASE

Specifying "noload" on the expert system command line causes the program to proceed directly to the CLIPS command prompt. This capability is desirable when a user or maintainer wishes to run only a subset of all the ONAV sensor subsystem rule sets. For example, if only Tacan related rules are needed for a special run then this feature of the ONAV Entry system should be used. The process to do this would begin first by loading the following files:

```
control.r
init.r
tables.r
operator.r
output.r
```

Because rule files are generally not in the directory from which the Entry expert system is invoked, the load command must utilize the full path name of the files to ensure proper loading. An example would be:

```
(load "exsys/control.r")
```

An alternative method of loading these "essential" rule sets would be to setup a CLIPS batch file containing the load commands desired. The loading of the essential rule files could then be accomplished by typing the CLIPS command:

```
(batch "<your batch file name with all load commands>")
```

After this has been done, then any other rule file(s) may be loaded as needed. It should be noted that a user will usually always want to load the rule file "hstd.r," as it contains some essential types of processing. This should be evaluated by a user or maintainer on an individual basis as to whether the hstd.r file is needed.

After loading all the necessary files, all of the currently available CLIPS commands and features would be used to execute and examine the rules that have been loaded. Using the Entry expert system to do such loading as opposed to

using the CLIPS expert system itself enables many ONAV Entry features to be available, particularly the externally defined functions which are frequently used in ONAV Entry rules.

6.2 EXECUTION IN THE SCROLLING MODE

An operating mode for ONAV Entry in some respects similar to the above described noload approach, is called scrolling mode. Scrolling mode allows the use of all CLIPS capabilities; e.g., printing facts or rules, limited execution, "watch", etc. This method of running the Entry expert system is particularly useful when testing and verifying rulebase and/or external function changes.

Figure 6.2-1 gives an example of running the expert system in scrolling mode. The entire rule base is first loaded and reset as in normal operation of the system. The RECYCLE command is then used to restart the data prep process and perform other background setup activity, somewhat analogous to the ONAV command used to invoke the expert system display as described earlier in this document.

At this point, one or more CLIPS commands are entered to enable various features of interest. Then the system is given the RUN command. Figure 6.2-2 shows an example where rule execution messages are requested during execution and then the system is started.

If the fact "(single step)" exists in the factbase (either through a deffacts statement in one of the rule files or through the use of the CLIPS assert command at the prompt), then CLIPS will halt at the end of the output phase. This allows the system to be run one ONAV cycle at a time.

It must be noted that asynchronous user input (via the system menu on the ONAV display) is NOT available in scrolling mode. So make sure the system is going to stop where you want it to stop before you start it when in scrolling mode. BREAK or DEL will halt CLIPS without terminating the process and bring you back to the CLIPS prompt, but it is NOT GUARANTEED TO LEAVE THE AGENDA IN THE CORRECT STATE! Therefore, once you interrupt a run in scrolling mode, you should start over by loading the system again to avoid any ambiguous results.

Figure 6.2-1: Setting Up the Expert System in Screen Mode

```
$ entry prep keyboard
Welcome to the Entry ONAV Expert System
Load in progress; please stand by...
loading control/data rules
loading landing site rules
loading state rules
loading imu rules
loading 3-state rules
loading drag rules
loading tacan rules
loading baro rules
loading msbls rules
loading hstd rules
loading telemetry rules
Don't forget to reset CLIPS
CLIPS> (reset)
CLIPS> (recycle)
configuration: runway KSC15
configuration: tacan -59
configuration: atmosphere nominal
configuration: bfs-status go
configuration: delta-state none
0
CLIPS>
```

Figure 6.2-2: Screen Mode Example Showing a Watch and Run

```
loading msbls rules
loading hstd rules
loading telemetry rules
Don't forget to reset CLIPS
CLIPS> (reset)
CLIPS> (recycle)
configuration: runway KSC15
configuration: tacan -59
configuration: atmosphere nominal
configuration: bfs-status go
configuration: delta-state none
0
CLIPS> (watch rules)
CLIPS> (run)
FIRE 1 control-kickoff: f-146
time: 12:59:35
FIRE 2 control-change-phases: f-147 f-146
FIRE 3 control-kickoff-subphase: f-647 f-151
FIRE 4 control-kickoff-subphase: f-647 f-154
FIRE 5 control-kickoff-subphase: f-647 f-226
FIRE 6 control-kickoff-subphase: f-647 f-230
FIRE 7 control-kickoff-subphase: f-647 f-239
FIRE 8 control-kickoff-subphase: f-647 f-280
```

The initial configuration cannot be changed while in the scrolling mode. You have to go to screen mode, change the configurations and return to scroll mode. Screen mode is where the ONAV Entry display is shown on the screen. Screen mode can be entered by typing the following command at the CLIPS prompt:

(screen-on)

This command activates the ONAV display and shows the CLIPS prompt in the lower left portion of the display where the configuration summary is normally displayed. In this situation, the system menu commands are active and configuration changes can be made as described earlier in this document. Then use:

(screen-off)

to return to scroll mode. An alternative is to use the "(onav)" command at the CLIPS prompt. This is the command that is used to invoke the system when beginning a normal run. In this case the configuration parameters can be changed, and then the hidden system menu command "z" can be used to return to the CLIPS prompt.

Remember, the configuration menu changes only the initial configuration of the parameters; a reset command on the display system menu must be done after setting the desired configuration parameters in order for the changes to take effect. There will be no indication of this on the screen, so take care in working very deliberately and carefully.

6.3 COMPILATION PROCEDURES

At various times, particularly when later releases of CLIPS are available for use in the ONAV Entry system or functions or features in the system are modified, it will be necessary to recompile the expert system code. In the top directory there is a "makefile" that recompiles the following 4 programs: entry, prep, keyboard, and msk.

If substantial recompilation is needed, you may want to redirect output and run in background by entering the following at the Unix system prompt:

make >file 2>&1 & ,where file is a junk file name

It is recommended that this type of syntax in the make command be used, because most compiler output goes to standard error, not standard output.

It is recommended that the following steps be followed to compile a new version of CLIPS:

- a. go to the CLIPS source directory and load the new source files from tape or floppy
- b. In the file clip.h, there are some flags which specify which operating system you are using. Make sure UNIX_V is 1 and all others are zero.
- c. Type the following Unix command, `cc -c *.c` to compile all the CLIPS source files.
- d. Remove the library of the old CLIPS by the command:
`rm libclips.a`
- e. Create the new CLIPS library with the following Unix command: `ar re libclips.a *.o`

6.4 DATA FILE PREPARATION FROM LOGTAPES

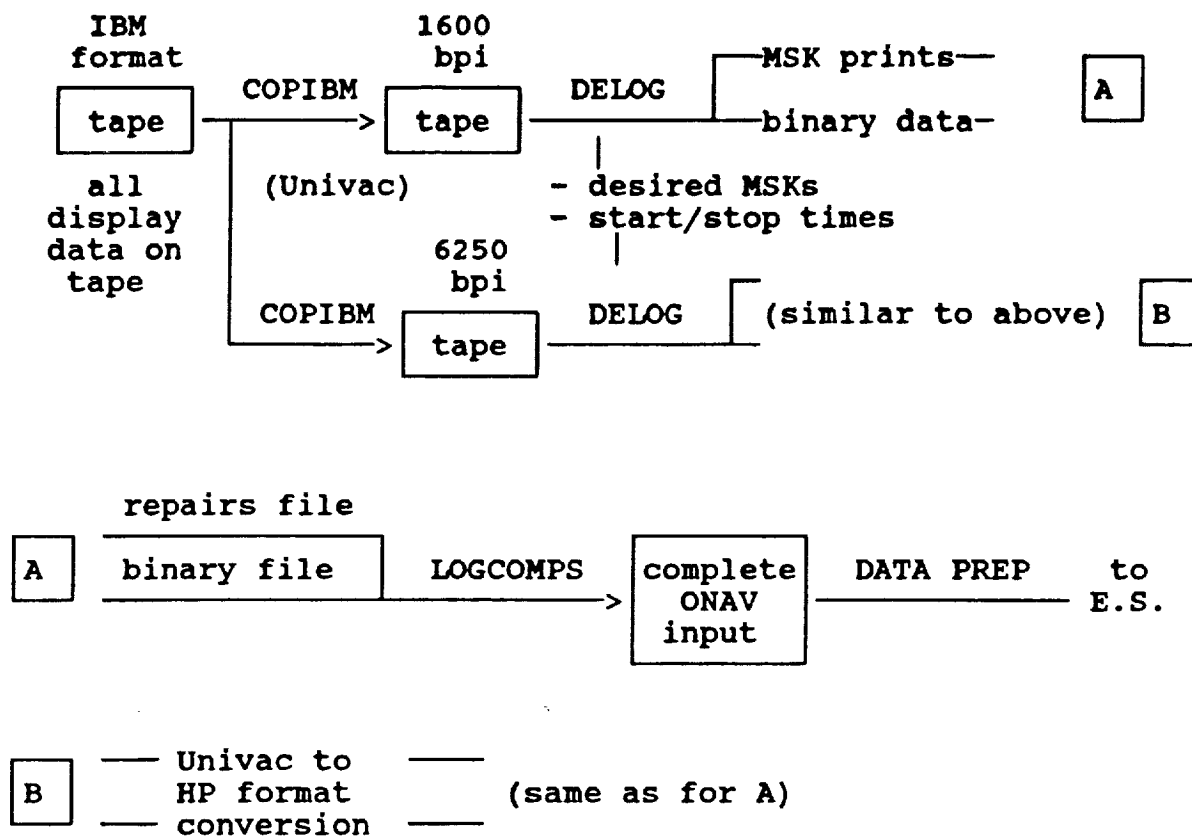
Logtapes from MCC simulations are used to generate data files for use by the current ONAV system. The overall process of generating a data set for use by the ONAV Entry system is illustrated in figure 6.4-1.

To create a data file for use, you must begin by obtaining a copy of the desired MCC tape at 1600 BPI. This procedure is defined by RSOC. Two tapes reels will likely be required for an typical Entry run, with about 6 minutes on each reel. Ideally, the time of the split between the reels should be at or shortly before a data dropout (static data); otherwise parameters which change infrequently will appear blank on the second reel.

See the HP DELOG user's guide for instructions on running DELOG. Only binary output is needed (file = delog.bin); printout and display output can be suppressed.

The ONAV Entry system support program called "logcomp" reads delog.bin, combines data from MSK 547, 548, and 545 with data repairs (see below) to produce comps.data, the input to data prep. After this processing is complete, move comps.data to the top directory of the ONAV Entry system for proper access by the expert system.

Figure 6.4-1: Data File Preparation Process Flow



6.5 DATA REPAIRS FILE

Data repairs is a capability provided in the logcomps program to handle both difficulties with incomplete data that is sometimes encountered with DELOG tapes, as well as permits a method of doctoring input data for specialized types of testing of rules that might be necessary on occasion.

The file repairs contains a list of changes to the log tape data in the following form:

```
days hrs mins secs _____ time of the repair
parm-id value
```

```
└── see data prep list (COMPS output index)
```

During logcomps processing the specified parameter is changed to the given value beginning at the specified time and continues until another repair of the same parm-di or until the end of the data file.

An operational note with respect to logcomps: the last line of repairs must be a time beyond the end of the log tape data. Otherwise, logcomp will get an end-of-file error.

6.6 DISPLAY SCREEN WINDOW DEFINITION

In the event that changes to the display window descriptions are desired, the following information is provided to assist in accomplishing such efforts. The background labels for the expert system display screen are defined in the file "windows". Each window is defined as follows:

```
#lines    #cols    top-line    left-side
-
- )text (number of lines = #lines)
-
```

This file is read by the module OUTPUT.C; the windows must appear in the file in the order that they are read by the program.

6.7 LANDING SITE TABLE

The landing site table information is important to ensuring that the ONAV Entry expert system has the correct information that corresponds to the flight data in use.

The landing site table (filename is: site) contains one line for each entry in the table according to the following format:

slot#	runway	MSBLS-chain	TACAN-chain	toggle
(1-30)				0 = not available 1 = available

6.8 GENERAL OPERATION NOTES

The following are miscellaneous items of information relevant to various aspects of the the ONAV system. Most of them are maintenance and implementation related.

- a) When activating the screen for the expert system, make sure that all CLIPS debug types of output are disabled before executing the system in screen mode.
- b) When using the EXIT command on the system menu of the ONAV display, it should be noted that the data prep process (Unix process) may survive the exit operation. To check this, do a "ps" Unix command to check system processes. If there is a process named "prep," then remove it with the "kill" Unix command (i.e., Kill -9 <process number of data prep obtained from the "ps" command).

Section 7

REFERENCES

- 1) "Guidelines and System Requirements For the Onboard Navigation (ONAV) Console Expert/Trainer System," NASA Johnson Space Center, Mission Support Directorate, Mission Planning & Analysis Division, JSC internal Note #JSC-22433, December 1986.
- 2) "Knowledge Requirements For the Onboard Navigation (ONAV) Console Expert/Trainer System, "Mission Support Directorate, Mission Planning & Analysis Division, NASA Johnson Space Center, ENTRY phase specifications, Baseline Version 1.0, October 1987, JSC internal Note #JSC-22657.
- 3) Design Specification For the Onboard Navigation (ONAV) Console Expert/Trainer System," NASA Johnson Space Center, ENTRY Component, preliminary July 10, 1987.
- 4) "HP DELOG User's Guide, Release 1.1," Unisys transmittal memo No. TM-TX-(L)-9560/589/00(01), September 4, 1987.
- 5) "CLIPS Reference Manual," NASA Johnson Space Center, Mission Planning & Analysis Division, AI section, Version 4.1, September 1987.

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